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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE HOUSTON MEETING

AT

RICE INSTITUTE

Houston, Texas

November 28–29, 1947

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NOVEMBER 28, 1947 Vol. 22, No. 5

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AMERICAN PHYSICAL SOCIETY

HOUSTON MEETING, NOVEMBER 28–29, 1947

THE **280th meeting of the American Physical Society,** being the 1947 Thanksgiving meeting, will be held at Houston, Texas, on Friday and Saturday, November 28 and 29, 1947. This will be our first meeting in Texas, so far, at least, as the memory of the Secretary goes. The geophysical interests of many of our Texan colleagues will be reflected in the programme; and the meeting will acquire an international character from the presence of several of our Mexican colleagues from the Universidad de Mexico. Our friends of Texas will undoubtedly be shocked to have their State described as "out of the way"; but since it *has* been out of our way heretofore, it is hoped that many of our members will make a special effort to attend this unprecedented meeting. Our host is the Rice Institute, in various buildings of which our sessions will be held.

Hotel. The headquarters of our Society is the Rice Hotel. Immediate reservation is requested and advised. To get to Rice Institute from the hotel, take the bus labelled South End 7400, passing the hotel on Main Street. In the mornings, busses pass the hotel at 8:26, 8:41, 9:13, and 9:38. Allow twenty-five minutes.

The **registration desk** will be located in the Physics Cloister of Rice Institute.

A **Symposium on Underground Applications of Physics** will be held in the Physics Amphitheatre on Saturday morning, commencing at 9:30. This symposium—a joint symposium with the Society of Exploration Geophysicists, for the planning of which we are indebted to L. L. Nettleton—will consist of four papers by Messrs. R. F. Beers, Gerhard Herzog, M. King Hubbert, and Paul Weaver.

Invited papers by T. W. Bonner, A. H. Compton, Benno Gutenberg, J. R. Haynes, W. V. Houston, T. C. Poulter, C. F. Squire, and M. S. Vallarta relate to a great variety of subjects well representing contemporary physics, and are distributed throughout Friday from morning into the evening.

Contributed papers are distributed in five sessions on Friday afternoon and on Saturday.

The **dinner** (informal) of the American Physical Society will be held at seven o'clock on Friday evening in the Rice Institute Commons, the price being $2.50. Members are requested to fill in and mail the reservation form printed on the inside back-cover page, so that the Local Committee may have some idea how many dinners to provide. Tickets will be available at the registration desk until 2 P.M. on Friday. There will be an after-dinner speech by A. H. Compton, "The Physicists' Role in International Relations."

Possible **excursions to laboratories** will be announced at the registration desk.

NOV 24 1947

The **Council** will meet at 4:45 P.M. on Friday in the office of President Houston at Rice Institute.

The **new Membership List** of the American Physical Society has at long last gone to press: the date of its appearance will depend upon conditions in the printers' workshop.

Future meetings of the Society are scheduled to be held at Chicago (December 29–31, 1947), Los Angeles (January 2–3, 1948), New York (January 29–31, 1948), and Washington (April 29–30, May 1, 1948). It is not too early to apply for reservations at the official hotels in Chicago (the Palmer House) and New York (the Hotel New Yorker).

General Rules Relating to Papers

The By-Laws of the Society stipulate that no contributed paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the American Physical Society not later than the closing date stated in the printed call for the meeting.

The time allowed for the oral presentation of a contributed paper is ten minutes at most.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of *The Physical Review*.

Karl K. Darrow, *Secretary*
American Physical Society,
Columbia University, New York 27, New York

PROGRAMME

FRIDAY MORNING AT 10:15

Physics Amphitheatre

(L. A. DUBRIDGE presiding)

Address of Welcome

PRESIDENT W. V. HOUSTON, *Rice Institute*

Invited Papers

The Low-Temperature Physics Programme at the Rice Institute. C. F. SQUIRE, *Rice Institute.* (30 min.)

Resonances in the Disintegration of Fluorine by Protons. T. W. BONNER, *Rice Institute.* (30 min.)

Certain Problems Concerning the Primary Cosmic Radiation. M. S. VALLARTA, *Universidad de Mexico.* (35 min.)

FRIDAY AFTERNOON AT 2:00

Chemistry Lecture Hall

(S. L. BROWN presiding)

A1. Graphical Solution of Non-Linear Simultaneous Equations. JAMES M. SHARP AND S. LEROY BROWN, *University of Texas.**—A pair of non-linear simultaneous equations in two variables, x, y, may be put in polar form by substituting $x=r\cos\theta$, $y=r\sin\theta$. If powers of $r\cos\theta$ and $r\sin\theta$ are expanded into harmonic functions of multiple angles, and any resulting products are expanded into functions of multiple angles, each of the original equations becomes harmonic in form with coefficients containing powers of the modulus r. Assign a value for r, and either harmonic equation may be graphed with a mechanical harmonic synthesizer as θ varies from zero to 2π. The roots from this graph will be points $x(=r\cos\theta)$, $y(=r\sin\theta)$ of the plot of the original equation in the $x-y$ plane. Successively chosen values of r locate other points and, thereby, the original equation is graphed. Each of the pair of equations is plotted in this way, and the intersections of these two curves will indicate the simultaneous values.

* Assisted by the Office of Naval Research.

A2. Graphical Solution for the Real and Complex Roots of Polynomials With a Mechanical Harmonic Synthesizer. ROBERT G. PACKARD AND S. LEROY BROWN, *University of Texas.**—The powers of the variable x in a polynomial may be expressed as harmonic functions of multiple angles by De Moivre's theorem, $x^n=r^n(\cos n\theta+j\sin n\theta)$. After this substitution in the polynomial the real terms give one equation, and the imaginary terms give the second equation of a pair of simultaneous equations with variables r and θ. Eliminate r between these two equations and there results an equation of harmonic terms in multiple angles. This resultant equation may be graphed with a mechanical harmonic synthesizer and its roots determined; that is, values of θ are found that satisfy this equation. These values of θ substituted into either of the simultaneous equations will determine the respective values of the modulus r. Thereby, the real components, $r\cos\theta$, and the imaginary components, $r\sin\theta$, of the roots of the original polynomial are determined.

* Assisted by the Office of Naval Research.

A3. Analytical Solution of Electrical Networks for Resonant and Antiresonant Frequencies. MARY GOWEN FOULKS, *University of Texas.**—Where the circuit constants of a several mesh network are specified, the resonant and antiresonant frequencies can be determined by a mechanical process. If the circuit is non-dissipative, either the resonant or the antiresonant frequencies may be apparent; moreover, the other critical frequencies can be found as the roots of the polynomial obtained by setting either the susceptance or the reactance, depending on the nature of the network, equal to zero. The solution of the polynomial is carried out by making a change of variable, transforming

the equation into a function of multiple angles which can be traced with a mechanical harmonic synthesizer. The angles at which the harmonic sum equals the constant term of the transformed equation give the roots of the polynomial. For a dissipative circuit the impedance as a function of the angular velocity is differentiated with respect to argument and the resulting expression equated to zero to calculate the resonant and the antiresonant frequencies; the polynomial is solved mechanically.

* Assisted by the Office of Naval Research.

A4. Graphical Solution of Network Impedances with a Mechanical Harmonic Synthesizer. S. LEROY BROWN, *University of Texas.**—The impedance of an electrical network of specified circuit constants is a complex function of frequency ($\omega=2\pi f$) in the form of a fraction with a real and a pure imaginary term in the numerator, and a common denominator. These terms will be high degree polynomials in ω. If ω is replaced by a harmonic function such as $r(1-\cos\theta)$, modulus r being chosen so that the desired range in values of ω is obtained as θ varies from zero to π, and if the powers of the new variable are expanded in terms of multiple angles, then the resulting functions can be graphed with a mechanical harmonic synthesizer. For pure reactance networks there will be only one term in the numerator, pure imaginary, and a denominator, but impedances will have both real and imaginary terms in the numerator; therefore, two functions must be plotted to solve non-dissipative networks and three to determine both the resistance and reactance of dissipative networks, these quantities being calculated from the ratios of corresponding ordinates of the graphs.

* Assisted by the Office of Naval Research.

A5. On the Dielectric Wave Guide of Circular Cross Section.* C. W. HORTON, *University of Texas.*—It has been known for a long time that a dielectric rod of circular cross section can be used as a transmission line for electromagnetic waves. When the mathematical theory of such waves is developed, one encounters a characteristic equation[1] of some complexity relating the wave-length in the rod to its radius and dielectric constant. This characteristic equation has been solved numerically for three modes of vibration. These are the transverse electric wave of radial symmetry, the transverse magnetic wave of radial symmetry, and the mode whose angular variation depends on $\sin\theta$. The last case is similar to the $TE_{1,1}$ mode in a circular metallic wave guide. For each of these cases the calculations have been carried out for the first two of the infinitely many branches. The tangential components of the electric and magnetic vectors, over the surface of the dielectric rod, have been computed. These quantities are necessary in order to calculate the radiation patterns of dielectric rods by Schelkunoff's method of equivalent surface currents.

* This work has been done in part under sponsorship of Bureau of Ordnance, Navy Department.

[1] J. A. Stratton, *Electromagnetic Theory*, p. 526, Eq. (9).

A6. Inversion of a Family of Laplace Transforms Associated to the Propagation of Electromagnetic Waves in Cylinders. MANUEL CERRILLO, *Massachusetts Institute of Technology. (Introduced by M. S. Vallarta.)*—In the study of the transient phenomena of the propagation of electromagnetic waves in cylinders, mainly in wave guides, one has to evaluate the inverse of a family of Laplace transforms of the type $F[s(s^2+b^2)^{\frac{1}{2}}]e\exp-a(s^2+b^2)^{\frac{1}{2}}$. In this paper is presented the compact solution in terms of Lommel's functions, as well as the asymptotic expansion and graphical methods to obtain these inverse functions.

A7. Bridged Double T Network. C. H. FAY, *Shell Oil Company.*—For what may be termed a bridged double T, with series impedances numbered Z_1, Z_3, Z_5, shunt impedances Z_2, Z_4, numbering being from the source end, and bridging impedance Z', the condition for zero output voltage is $Z_1[Z_3Z_4+(Z_2+Z_3+Z_4)Z_5]+Z_2[Z_3Z_5+Z_4(Z_1+Z_3+Z_5+Z')]=0$. A special case of interest is $Z_1=Z_3=Z_5=R$, $Z_2=Z_4=(j\omega C)^{-1}$, which for $Z'=12(j\omega C)^{-1}$ has a null at a frequency given by $R\omega C=\sqrt{3}$. The "inverse" case, $Z_1=Z_3=Z_5=(j\omega C)^{-1}$, $Z_2=Z_4=R$, has for $Z'=12R$ a null for $R\omega C=1/\sqrt{3}$. An application to a substitution bridge for measurement of small direct capacitances in the presence of large admittances to ground, with provision for measuring small conductive components, is discussed; it has the advantage that admittances to ground appear only as shunts on source and detector, and thus affect the sensitivity only.

A8. An Electronic Control Device for the Stabilization of a 10,000-Oersted Magnetic Field. D. S. HUGHES, W. L. PONDROM, AND G. B. THURSTON, *University of Texas.*—It was desired to stabilize the magnetic field of a low voltage, high current electromagnet at the University of Texas. The field, to be used in connection with a mass spectrograph, was to be held at 10,000 oersteds$\pm\frac{1}{2}$ oersted for several successive minutes. The device developed is a feed-back control system operating directly from and on the field. An armature located in the field and driven by a synchronous motor yields a 3-phase voltage which is rectified and filtered so that a d.c. voltage is obtained which is directly proportional to the magnetic field with negligible lag. Variations in this d.c. voltage are amplified, the amplified voltage variations controlling the operation of power triodes, which in turn regulate the current in auxiliary coils attached to the pole pieces of the magnet. Thus variations in the magnetic field are amplified and converted into the compensating field of the auxiliary coils on the magnet. Field drifts of $\pm$120 oersteds, and rapid field variations as fast as 0.25 second and as great as 150 oersted are reduced to $\pm$0.25 oersted, over-all variations being held within $\frac{1}{2}$ oersted for 10 minute intervals.

FRIDAY AFTERNOON AT 2:00

Physics Amphitheatre

(H. A. WILSON presiding)

Invited Papers

Normal Vibrations in Crystals. W. V. HOUSTON, *Rice Institute.* (30 min.)

Behavior of Photoelectrons in Silver Chloride Crystals Exhibited by Colloidal Silver Produced at Electron Traps. J. R. HAYNES, *Bell Telephone Laboratories.* (30 min.)

FRIDAY AFTERNOON AT 3:30

Physics Amphitheatre

(L. L. NETTLETON presiding)

Invited Papers

Microseisms and Hurricanes. BENNO GUTENBERG, *California Institute of Technology.* (30 min.)

Seismic Measurements in the Antarctic. T. C. POULTER, *Armour Research Foundation.* (30 min.)

FRIDAY EVENING AT 7:00

Rice Institute Commons

(L. A. DUBRIDGE presiding)

Dinner of the American Physical Society

AFTER-DINNER ADDRESS

The Physicists' Role in International Relations. A. H. COMPTON, *Washington University.*

SATURDAY MORNING AT 9:45

Physics Amphitheatre

(L. A. DUBRIDGE presiding)

Joint Symposium of the American Physical Society and the Society of Exploration Geophysicists

Underground Applications of Physics

Field Equations of the Flow of Liquids through Porous Solids. M. KING HUBBERT, *Shell Oil Company.* (35 min.)

Seismic Travel Paths at Bikini Atoll. R. F. BEERS, *Geotechnical Corporation.* (35 min.)

Physical-Chemical Interpretation of a Geological Problem: Rocks from Sea Water. PAUL WEAVER, *Gulf Oil Corporation.* (35 min.)

Industrial Applications of Radioactivity. GERHARD HERZOG, *Texas Company.* (35 min.)

SATURDAY MORNING AT 9:45

Chemistry Lecture Hall

(T. W. BONNER presiding)

E1. The Rice Institute Van de Graaff Electrostatic Generator. H. A. WILSON, *Rice Institute.*—This note contains a description of some of the novel features of the Rice Van de Graaff machine, including the electrostatic voltmeter, the flexible joint between the vacuum tube and the end of the tank, and the method of making the aluminum rings.

E2. A Pair Production Spectrometer for Gamma-Rays.* NELSON JAMES TERRELL, JR., *Rice Institute.*—A pair production spectrometer has been designed for the purpose of measuring high gamma-ray energies (3–15 Mev). Electrons and positrons, ejected from a lead radiator, travel in 180° arcs in a uniform magnetic field and are detected by four Geiger counters, two near the focal point of each beam. Electron-positron coincidences are determined as a function of field strength, and the particle energy, E_m, corresponding to the maximum counting rate should determine the gamma-ray energy by the relation $E_\gamma = 2E_m + 1.02$ Mev. Preliminary tests have been made with radium as a source of gamma-rays; however, the low energy and complex nature of the radium spectrum make it an unsuitable source for this apparatus. It is planned to extend the tests to ThC″.

* This work was supported by the Office of Naval Research.

E3. Separation of Li Isotopes.* WARD WHALING AND J. E. EVANS, *Rice Institute.*—A mass spectrometer has been constructed in order to collect the isotopes of the light elements in sufficient quantity for nuclear-bombardment experiments. A 30° sector-shaped magnetic field is used to focus a parallel beam of ions emitted from an extended source. Such a lens does not provide theoretically perfect focusing, but the width of the focused image resulting from this imperfection is negligible compared to other factors unavoidable in a high intensity instrument, and its simplicity recommends it. By the use of a heated platinum wire, coated with Amblygonite (Li Al(F, OH) PO_4) as a source of Li ions, satisfactory resolution of the Li isotopes has been attained at low ion currents. Further work is under way to maintain this resolution at the full intensity of which the instrument is capable.

* This work was supported by the Office of Naval Research.

E4. Some Characteristics of Scandium (46).* C. E. MANDEVILLE AND MORRIS V. SCHERB, *Bartol Research Foundation.*—Sc_2O_3 was irradiated by slow neutrons in the Clinton pile. The radioactive material was separated into phosphorous, iron, calcium, and scandium. The beta-rays emitted by the scandium fraction had an end point of 0.076 g/cm² in aluminum. The maximum energy of the gamma-rays was found to be 1.0 Mev by coincidence absorption. The beta-gamma coincidence rate was 1.4×10^{-3} coincidence per beta-particle, and was independent of the beta-ray energy. A gamma-gamma-coincidence rate of $(0.62 \pm 0.06) \times 10^{-3}$ coincidence per gamma-ray was also observed. These coincidence rates suggest that each beta-ray is followed by two gamma-rays. A search was made for the hard beta-rays reported to be emitted by this isotope.[1,2] None were found.

* Supported by the Office of Naval Research.
[1] H. Walke, Phys. Rev. **57**, 163 (1940).
[2] Peacock and Wilkinson, Phys. Rev. **72**, 251 (1947).

E5. The Thin Target Yield of the Gamma-Rays from the Disintegration of Beryllium by Deuterons.* C. P. SWANN, W. J. SCOTT, E. L. HUDSPETH, AND C. E. MANDEVILLE, *Bartol Research Foundation.*—The bombarding particles were supplied by the 0.4 microampere magnetically analyzed beam of the Van de Graaff generator at the Bartol Research Foundation. The electrostatic voltmeter was calibrated by the 440-kv resonance of the gamma-rays from lithium plus protons. The thin target yield of the gamma-rays emitted in the disintegration of beryllium by deuterons has been investigated for deuteron energies ranging from 150 kev to 750 kev. The yield was found to rise smoothly with increasing bombarding energy, with no evidence for resonance on the voltage interval under study. With the assumption that the gamma-rays are related to the neutrons from this reaction, the curve agrees fairly well with the theoretically calculated yield.[1] The absolute yield at 600 kv from the thin target (stopping power 35 kev) was estimated to be about 7.5×10^{-7} quantum per deuteron.

* Supported by the Office of Naval Research.
[1] H. A. Bethe, Rev. Mod. Phys. **9**, 69 (1937).

E6. Gamma-Rays and Neutrons from Beryllium Bombarded by Deuterons. C. W. MALICH* AND J. R. RISSER, *Rice Institute.*—The thin target yields of gamma-rays and of neutrons from beryllium bombarded by deuterons have been determined for bombarding energies from 0.25 Mev to 1.7 Mev. The gamma-rays were detected with a self-quenching Geiger-Mueller counter, and the neutrons with a proportional counter filled with argon at atmospheric pressure. The excitation functions of both the neutrons and the gamma-rays are similar; the yields increase approximately exponentially with bombarding energy up to a deuteron energy of about 1 Mev, and less rapidly at higher energies. No resonances were observed.

* Now at the University of Pennsylvania.

E7. Further Evidence for a $\gamma - p$ Process in Be^9. RICHARD L. CONKLIN* AND WILLIAM OGLE, *Los Alamos Scientific Laboratory.*—A previous paper[1] has reported observation of a $\gamma - p$ process in Be^9. In that work the 12-Mev beta-particles from the decay of Li^8 were observed above the

background of 3.7-Mev betas from He^6, also formed during the irradiation by the process $Be^9(n, \alpha)He^6$. Li^8 decays into Be^8,* which promptly breaks up into two alpha-particles. The observation of these alphas should furnish further proof of the presence of Li^8. Such an experiment has been performed, and alpha-particles have been observed from beryllium after irradiation by 20-Mev x-rays. The decay half-life is within experimental error of the 0.88-second half-life of Li^8.

* Now at the University of Illinois, Urbana, Illinois.
[1] Ogle, Brown, and Conklin, Phys. Rev. 71, 378 (1947).

E8. Differential $D(d,n)He^3$ Cross Section for 10-Mev Deuterons. B. R. CURTIS, LOUIS ROSEN, AND J. L. FOWLER, *Los Alamos Scientific Laboratory.*—Deuterons from the Los Alamos cyclotron, focused at the center of a scattering chamber, were used to bombard a thin gas target and the number of He^3 particles observed which were emitted into a known solid angle in a given direction. Several gas targets were used so that, in the laboratory system, all angles from 20 to 42 degrees with the direction of the beam could be measured. The He^3 pulses were recorded by means of a proportional counter and amplifier and were analyzed with a ten-channel amplitude discriminator. The resulting plot of pulses per amplitude interval against amplitude gave a peak well resolved from background. The deuteron current was measured by means of a Faraday cage and current integrator. The value of the deuteron energy determined by magnetic deflection was 10.2 Mev, which value remained constant to about two percent throughout the experiment. From the number of He^3 counts obtained in a given experiment and the integrated current the differential cross sections were calculated. These data indicate that in the center of mass system the differential cross section for the production of He^3 particles from this reaction is approximately independent of angle from 70 to 130 degrees. The total cross section obtained by extrapolation of the data is 0.04×10^{-24} cm^2.

E9. The Scattering of Neutrons of Energy Between 12.0 Mev and 13.0 Mev by Protons. J. S. LAUGHLIN AND P. G. KRUGER, *University of Illinois.*—The angular distribution of the recoil protons projected during the scattering of neutrons by protons has been investigated in a methane-filled high pressure cloud chamber. A deuterium gas target bombarded with 10-Mev deuterons provided the high energy neutron source. The spectrum of the neutrons from this source, which entered the cloud chamber through a collimator, was surveyed, and showed a group of high energy neutrons superimposed on a continuous background. Examination of the data with selection criteria to determine those recoils projected by the scattering of neutrons between 12.0 Mev and 13.0 Mev yielded a total of 1573 recoil protons. The azimuthal and recoil angle distributions of these protons have been analyzed. Analysis of the data employing calculated azimuthal-correction factors yielded an angular distribution which agreed satisfactorily with an analysis based on only the 699 recoils which fell in azimuthal zones for which the azimuthal correction factor was unity. A ratio of the differential cross sections for neutron scattering in the backward direction to scattering in a direction perpendicular to that of the incident neutron beam, of unity (spherically symmetric scattering) or slightly greater than unity can be consistent with these data.

E10. The Scattering of Fast Neutrons by Mercury.* G. C. PHILLIPS AND J. C. HARRIS, *Rice Institute.*—The scattering of fast neutrons by mercury has been investigated, using the neutrons from the D^2+D^2 reaction and an ethane- and ethyl alcohol-filled cloud chamber placed at right angles to the deuteron beam. About 4500 stereoscopic photographs were taken, half with a hemispherical mercury scatterer against the target and in the direction of the beam, and half without the scatterer. Two hundred and sixty-three recoil protons, which were directed within 10° of the normal at the target to the incident beam, were measured. The energy distribution of the neutrons scattered from the mercury was calculated from the difference in the energy distributions of the recoil protons, with and without the scatterer. The number *vs.* energy plot for the neutrons indicated an increasing yield in the number inelastically scattered all the way up to 2.0 Mev, and showed no maximum at low energies, as is predicted by theory.[1] Also neutrons were observed at energies almost up to the maximum for the reaction, thus showing that there is considerable backward scattering of the neutrons by mercury.

* This work was supported by the Office of Naval Research.
[1] V. Weisskopf, Phys. Rev. 52, 295 (1937).

SATURDAY AFTERNOON AT 2:00

Chemistry Lecture Hall

(M. S. VALLARTA presiding)

F1. The 440-Kev Resonance of Li^7+H^1.* J. E. EVANS AND T. W. BONNER, *Rice Institute.*—The gamma-ray resonance at 440 kev for lithium bombarded by protons has been re-examined[1,2] with thin targets and with the high resolution made available by the electronically regulated Rice Institute Van der Graaff generator. The resonance appears to be a singlet whose width at half-intensity is 14 kev. The cross section for the reaction at the peak of the resonance is found to be 4.4×10^{-27} cm^2. The previously reported [1] asymmetry of the excitation curve for the reso-

nance was confirmed. Attempts to explain the asymmetry on the basis of the barrier penetrabilities have not been successful.

* This work was supported by the Office of Naval Research.
[1] C. M. Hudson, R. G. Herb, and G. J. Plain, Phys. Rev. **57**, 587 (1940).
[2] L. R. Halfstad, N. P. Heydenberg, and M. A. Tuve, Phys. Rev. **50**, 504 (1936).

F2. A Study of the Narrow Resonance at 1430 Kev in the Reaction $C^{12}+H^2$.* J. C. HARRIS, T. W. BONNER, J. E. EVANS, AND G. C. PHILLIPS, *Rice Institute.*—The improved resolution of the Rice Institute pressure Van de Graaff machine has made possible a closer study of the half-width of the gamma-ray resonance in the reaction:

$$C^{12}+H^2 \rightarrow {}^*N^{14} \rightarrow {}^*C^{13}+H^1-0.52 \text{ Mev.}^1$$

By the use of a Geiger counter surrounded by lead the half-width was found to be 8 kev for a carbon target 2 kev thick. The cross section at the peak of the resonance was calculated to be 0.08×10^{-24}, using a value of 2 percent as the efficiency of the counter for the 3-Mev radiation. Work is in progress to make sure there are no competing neutrons from the decay of this excited state in N^{14} according to the reaction: $C^{13}+H^2 \rightarrow {}^*N^{14} \rightarrow N^{13}+n-0.28$ Mev.

* This work was supported by the Office of Naval Research.
[1] W. E. Bennett, T. W. Bonner, E. Hudspeth, H. T. Richards, and B. E. Watt, Phys. Rev. **59**, 781 (1941).

F3. A Study of the Distribution of Polonium on Thin Silver and Bismuth Films. FRED J. MORRIS AND ARTHUR E. LOCKENVITZ, *University of Texas.*—Thin films of silver and of bismuth were prepared by vaporization in a vacuum. Polonium was deposited on these films by chemical replacement from a solution of RaD with RaE and RaF. The distribution of the polonium on these films was studied by obtaining a pinhole camera photograph of the surfaces by means of the alpha-particles emitted by the polonium. Eastman fine-grain, alpha-particle plates were used. Microphotographs of these plates were made.

F4. Directional Correlation between Successive Beta- and Gamma-Emissions. D. L. FALKOFF AND G. E. UHLENBECK, *University of Michigan.*—The theory of the angular correlation between successive β- and γ-rays has been worked out. The method is analogous to that for $\gamma-\gamma$ angular correlation.* In contrast to the $\gamma-\gamma$ case, the $\beta-\gamma$ angular correlation depends not only on the angular momenta of the nuclear states but also on the upper energy of the β-spectrum, on the nuclear charge, and on the choice of the form of the β-interaction. For example, for a first forbidden scalar or Fermi β-transition followed by a dipole γ-ray, the angular correlation is of the form $1+C\cos^2\theta$, where for a $J-1$, J, J transition

$$C=\frac{2J+3}{6J-1-10JB(W_0, Z)}.$$

For the scalar interaction and Z small $B=-4/3$ for $W_0\gg1$ and $B=(-16/33)$ (W_0-1) for $W_0-1\ll1$. For the vector interaction, assuming a relation between nuclear matrix elements, the corresponding values for B are 8/3 and 3 (W_0-1). The angular correlation will provide, therefore, a test for the β-interaction. There is no angular correlation for allowed β-transitions.

* D. Hamilton, Phys. Rev. **58**, 122 (1940).

F5. Captura de Mesotrones Negativos por Protones. F. E. PRIETO CALDERON, *Universidad de Mexico. (Introduced by M. S. Vallarta.)*—Se estudian en este trabajo la posibilidad de que existan átomos de estructura análoga a la del hidrógeno, formados por un protón como núcleo y un mesotrón negativo, y las características de dicho átomo. Suponiendo que el camp de fuerzas entre el protón y el mesotrón es Coulombiano, se resuelve la ecuación de Schrödinger ye se encuentran las funciones de distribución angular y radial así como los valores permitidos de la energía. Se encuentra que la frecuencia de las radiaciones emitidas es del órden de las de los rayos X.

F6. Electron Showers at 30,000-Foot Elevation.* PAUL E. LLOYD, R. RONALD RAU, CARL D. ANDERSON, AND RAYMOND V. ADAMS, *California Institute of Technology.*—Out of a series of cloud-chamber photographs taken in a B-29 airplane at 30,000-ft. elevation, 3900 have so far been analyzed with respect to the frequency of occurrence of single particles and of electron showers. The magnet cloud chamber is the same as that previously used on Pikes Peak (14,100-ft. elevation) and at Pasadena (800-ft. elevation), and thus a comparison may be made at the three elevations. The cloud chamber is 17 cm in diameter in a magnetic field of 7500 gausses, and is actuated by means of two Geiger counters, one above and one below the cloud chamber. Single tracks were found to occur per unit time 2.7 and 13.3 times as frequently at 14,100 ft. and 30,000 ft., respectively, as at 800-ft. elevation. Corresponding values for electron showers, classified as to size of shower, are given in the table.

No. of particles in shower		2–4	5–10	11–100
Frequency of occurrence per unit time relative to that at 800-ft. elevation	14,100 ft.	9	21	29
	30,000 ft.	85	200	210

* The research described in this abstract was supported in part by the U. S. Navy.

F7. The Distribution in Energy of Cosmic-Ray Mesotrons and Protons at 30,000-Foot Elevation.* RAYMOND V. ADAMS, PAUL E. LLOYD, R. RONALD RAU, AND CARL D. ANDERSON, *California Institute of Technology.*—The momentum distribution of single cosmic-ray particles has been measured in a 17-cm cloud chamber in a 7500-gauss magnetic field at an altitude of 30,000 ft. The chamber was actuated by Geiger counters, one above and one below the chamber. Only single particles were measured in order to eliminate "shower" electrons. Of a total of 245 tracks measured, 40 could not have actuated both counters and are classified as random tracks, and 29 tracks had momenta greater than 1.5×10^7 gauss-cm and cannot be classified according to sign of charge. For the remaining 176 tracks, in the momentum range 1×10^6 to 1.5×10^7 gauss-cm, the ratio of positive to negative tracks is 2:1, which fact contrasts with the approximately equal numbers of positives and negatives found at sea level. The hypothesis that the

excess of positive particles consists almost entirely of protons is supported by the large number of particles among the low energy tracks (including random tracks) which are recognizable as protons, and the fact that the spectrum of the excess positive particles has a sharp cut-off at the lower momentum end at 1.3×10^8 gauss-cm, which is the minimum momentum that a proton must have to penetrate to the bottom counter. Thus, while cosmic-ray protons are relatively scarce at sea level, at 30,000-ft. elevation they constitute about one-third of the single particles in the above momentum range.

* The research described in this abstract was supported in part by the U. S. Navy.

F8. A Small Radial Cloud Chamber for High Altitude Operation.* R. B. LEIGHTON AND CARL D. ANDERSON, *California Institute of Technology.*—A cloud chamber 10 cm in diameter and 5 cm deep, arranged to compensate automatically for temperature changes over a 20°C range, has been built for operation at high altitudes in free balloon experiments. The cloud chamber, as yet without magnetic field or Geiger-counter control, is expanded regularly every 40 seconds. Power to operate the chamber and the camera is obtained from a small tank of liquid Freon. One 300-volt battery supplies power for the light source and the sweep field. Stereoscopic photographs are made on 35-mm film. The gross weight of the equipment is 20 lb. Out of a total of three flights in September, 120 track photographs were obtained at altitudes up to 80,000 feet above sea level, 55 being at the highest altitude. Numerous cases of electron showers and heavily ionizing particles were observed.

* The research described in this abstract was supported in part by the U. S. Navy.

F9. Photoelectric Effect in a Self-Quenching Geiger-Müller Counter.* M. V. SCHERB, *Bartol Research Foundation. (Introduced by W. F. G. Swann.)*—Geiger-Müller photon counters have had limited applications principally because their cathode surfaces have their spectral response in the 2000–3000A region.[1] A method has been discovered for treatment of a G-M photon counter which produces a marked change in the photoelectric properties of the cathode surface. By means of a discharge treatment at liquid-air temperatures of a G-M counter (copper cathode) filled with an argon-butane self-quenching mixture, the following effects have been noted: (1) The spectral response curve has been shifted to the longer wave-lengths—the peak response from 2250A to 3000A and the photoelectric threshold from approximately 2900–3000A to 3500A. (2) The relative increase in sensitivity at the peak response is a factor of at least 15. (3) No long-term fatigue of the photoelectric surface has been observed over a period of months. No changes in the normal properties of the Geiger-Müller counter such as background, useful life, starting voltage, pulse shape, and plateau characteristics have been observed after treatment. Applications of such sensitized photon counters are being considered, and work is proceeding in the investigation of the phenomena for various gases and cathode surfaces.

* Supported by the Office of Naval Research.
[1] O. S. Duffendack and W. E. Morris, J. Opt. Soc. Am. **32**, 8 (1942).

F10. The Effective Path Length through a Vertical Cosmic-Ray Telescope.* ENOS E. WITMER, *University of Pennsylvania,* AND MARTIN A. POMERANTZ, *Bartol Research Foundation.*—In cosmic-ray absorption experiments the separation between extreme counters has usually been taken as the distance traversed through the telescope. For a $\cos^2\theta$ distribution of intensity with zenith angle θ:

$$\frac{\bar{L}}{L}=\frac{\frac{3l}{L}\tan^{-1}\frac{l}{L}}{4\left[1+\left(\frac{l}{L}\right)^2\right]^{\frac{1}{2}}}-\frac{2}{\left[1+\left(\frac{l}{L}\right)^2\right]^{\frac{1}{2}}}, \tag{1}$$

where $\bar{L}$ is the average path length of a cosmic-ray particle through the coincidence counter train, L is the separation between extreme counters, and 1 is the length of each counter tray. For an isotropic distribution

$$\bar{L}/L=\frac{\frac{l}{L}\tan^{-1}\frac{l}{L}-\frac{1}{2}\log\left[1+\left(\frac{l}{L}\right)^2\right]}{\left[1+\left(\frac{l}{L}\right)^2\right]^{\frac{1}{2}}-1}. \tag{2}$$

In both cases, if $l/L\equiv u<0.9$,

$$\bar{L}=L\left\{1+\frac{1}{12}u^2-\frac{17}{360}u^4+\frac{25}{756}u^6-\cdots\right\}$$

gives a result accurate to within 1.0 percent. This is of particular significance in connection with Abstract F11.

* This work has been supported in part by the Office of Naval Research.

F11. The Properties of Cosmic-Rays at Very High Altitudes.* MARTIN A. POMERANTZ, *Bartol Research Foundation.*—A series of free balloon flights has provided data regarding the penetrating power of cosmic-ray particles up to altitudes appreciably exceeding those previously attained by balloon-borne equipment. As of October 11, fourteen flights have been conducted in this specific program, utilizing a standardized apparatus which transmits data by radio to the ground station. Several ascents have exceeded 100,000 feet, the remainder generally surpassing 90,000 feet. A confirmed altitude of 129,000 feet (~2 mm of Hg), establishing a new record for free balloons, was registered in one instance. Intensity *versus* altitude curves have been obtained with identical vertical quadruple coincidence-counter trains containing various thicknesses of Pb up to 7.5 cm, as well as 7.5 cm of C. Absorption curves for cosmic-ray particles at any altitude are thus available from the data. Among the salient features of the results are the following: 1. All of the intensity *versus* altitude curves converge at the top of the atmosphere. 2. The curves display a maximum with interposed absorber thicknesses up to 4 cm, but less than 6 cm of Pb. 3. Curves for the total radiation, and for that penetrating 7.5 cm of Pb, are in good accord with those obtained by others.[1]

* This work has been supported by the Office of Naval Research.
[1] G. Pfotzer, Zeits. f. Physik **102**, 23 (1936); M. Schein, W. P. Jesse, and E. O. Wollan, Phys. Rev. **59**, 615 (1941).

SATURDAY AFTERNOON AT 2:00

Physics Amphitheatre

(W. V. HOUSTON presiding)

G1. On the Hypotheses Underlying Any Theory of Gravitation. ALBERTO BARAJAS, *Universidad de Mexico. (Introduced by M. S. Vallarta.)*—In this paper we discuss the general form of a theory of gravitation in which the principle of equivalence holds. The trajectories are shown to be paths. The additional conditions are established to obtain Newton's, Einstein's, and Birkhoff's theories of gravitation.

G2. Foundation of Birkhoff's Theory of Gravitation on Particle Mechanics. CARLOS GRAEF FERNANDEZ, *Universidad de Mexico. (Introduced by K. K. Darrow.)*—In this paper postulates are set up on which Birkhoff's theory of gravitation can be based. The reference frame used is Minkowski's space-time of Einstein's special relativity. The field is characterized by Birkhoff's gravitational tensor. The velocity of a gravitational perturbation in empty space is assumed to be that of light. The forces acting between particles, at rest in an inertial reference frame, are—supposed to be Newtonian. The field tensor due to a particle at rest is obtained from the postulates with the help of considerations of symmetry. The gravitational field of a particle moving with constant velocity follows therefrom by a Lorentz transformation. For an accelerated particle it is assumed that its field is instantaneously identical with that of a particle of equal rest mass at rest in the instantaneous rest system. The perfect fluid, which Birkhoff originally used to establish his theory, does not appear in the postulates; all conditions refer to fields due to particles. In close analogy with Newton's gravitational theory one can base Birkhoff's theory on particle mechanics.

G3. Motion of a Particle on the Axis of a Rotating Ring in Birkhoff's Theory of Gravitation. FERNANDO ALBA, *Universidad de Mexico. (Introduced by M. S. Vallarta.)*—By the use of the potentials given by Birkhoff's theory, the equation of motion of a particle on the axis of a rotating ring can be found. The relativistic mass of the ring is found to be

$$m = m_0\left(1-\frac{3}{2}\frac{v^2}{c^2}\right).$$

The first integral of the equation of motion offers no difficulties, while the second requires series expansions. In this way a good approximate solution is obtained for amplitudes of the motion which are small compared with the radius of the ring. The Newtonian solution of the problem leads to elliptic integrals of the first and third kinds. The solution of this problem in the new theory is the same as the Newtonian solution for small values of the velocity of the particle, as it should be.

G4. Model Solar Atmospheres. GUIDO MUNCH, *Universidad de Mexico. (Introduced by M. S. Vallarta.)*—In this paper the model solar atmospheres considered earlier by Bengt Strömgren (Publikationer og mindre Meddelelser fra Kobenhavns Observatorium, Nr. 138, 1944) have been revised, using the recent determination of the continuous absorption coefficient of the negative ion of hydrogen by Chandrasekhar and Breen (Ap. J. **104**, 429 (1946)). The mean absorption coefficients have been obtained in the manner pointed out by Chandrasekhar (Ap. J. **101**, 238 (1945)) and with the temperature distribution of a gray atmosphere. The values of the opacity per gram, $\bar{\kappa}$, the total pressure, p, and the electron pressure, p_e, at a number of depths in the range $0.01 \leq q \leq 1.4$ are tabulated for the different values of the hydrogen-metal ratio considered. It is found that the values of p and p_e are systematically lower than those given by Strömgren, while the values of $\bar{\kappa}$ are higher by factors of the order of 1.2 for layers with $q \geq 0.02$. These departures of the parameters that determine the physical structure of a model atmosphere, from those evaluated by Strömgren, are most relevant for the layers on which the Fraunhofer lines arise. As a consequence, it might be important to use these new models when a rediscussion of the chemical composition of the solar atmosphere is undertaken.

G5. A Comparison of the Relative Molecular Stopping Power of $_1H^1$ and of $_1D^2$. ROLAND W. SCHMITT, T. N. HATFIELD, AND ARTHUR E. LOCKENVITZ, *University of Texas.*—The relative molecular stopping power of ordinary hydrogen was compared with that of deuterium, using the apparatus described by Colby and Hatfield.[1] Within the limits of experimental error the stopping power of these two gases is the same.

[1] M. Y. Colby and T. N. Hatfield, Rev. Sci. Inst. **12**, 62 (1941).

G6. A Comparison of the Relative Molecular Stopping Power of Some Hydrocarbon Isomers for Alpha-Particles from Polonium. THOMAS E. GIBBS AND ARTHUR E. LOCKENVITZ, *University of Texas.*—The hydrocarbon isomers, *N*-butane and isobutane, and butene-1, butene-2 and isobutene were used in this study. The specific ionization method, with the apparatus described by Colby and Hatfield,[1] was used for determining the extrapolated ionization range. The relative molecular stopping powers with respect to air at 760 mm and 15°C are:

N-butane	2.905±0.006
isobutane	2.907±0.006
butene-1	2.691±0.006
butene-2	2.690±0.006
isobutene	2.696±0.006

[1] M. Y. Colby and T. N. Hatfield, Rev. Sci. Inst. **12**, 62 (1941).

G7. The Measurement of the Relative Molecular Stopping Power of Gases for Polonium Alphas. T. N. HATFIELD AND M. Y. COLBY, *University of Texas.*—Measurements have been made of the relative molecular

stopping power of some twelve gases, using the specific ionization method of Colby and Hatfield.[1] The additive law for atomic stopping powers is found to hold for all gases measured if the stopping powers of the constituents are known. The assumption that the law holds for the other gases measured makes it possible to calculate the relative atomic stopping power of sulphur, carbon, chlorine, and iodine.

[1] M. Y. Colby and T. N. Hatfield, Rev. Sci. Inst. 12, 62 (1941).

G8. Capture of Electrons by Ions. JULIAN K. KNIPP, *Iowa State College.*—The Oppenheimer-Brinkman-Kramers theory of the capture of electrons by alpha-particles in their passage through matter is reformulated in terms of a momentum representation of the electrons. A Thomas-Fermi treatment of the atoms with which the particles collide gives capture cross sections in air in good agreement, except for extreme values of the particle velocity, with cross sections calculated from a Hartree model. Capture into excited electronic states becomes of primary importance for heavy ions carrying a core of electrons. Total cross sections for such ions are estimated assuming hydrogen-like representations for the electron in the captured state and the Thomas-Fermi model for the atom from which capture takes place.

G9. An Electronic Intensity Regulator for a Hydrogen Discharge Tube. W. L. PONDROM AND W. W. ROBERTSON, *University of Texas.*—In absorption spectrophotometry there is considerable need for sources which are accurately constant in intensity and are of reasonably high intensity. However, such sources are difficult to obtain. Experience has shown that commercial regulators of the resonance transformer or saturated core-type are only moderately successful in keeping constant the intensity of a discharge tube. An electronic regulator has been devised in this laboratory to control the intensity of a 2.5-kva Hanovia hydrogen discharge tube used as a source of continuous radiation in the 2500–3000A spectral region. The output of a photo-cell placed at the rear window of the discharge tube controls the value of an impedance in series with the primary of the high voltage transformer in such a manner as to correct for variations in the intensity of the source. Imposed variations in line voltage of ±6 percent cause negligible variations in the intensity as determined spectrophotometrically and also in terms of the output of a photo-cell, the maximum change in the photo-cell current being less than 0.1 percent with the regulator working and about 20 percent without using the regulator.

G10. The Effect of O-Deuteration and Substitution on the Ultraviolet Absorption Spectrum of Phenol. W. W. ROBERTSON, F. A. MATSEN, AND A. J. SERIFF, *University of Texas.*—The substitution of deuterium for the hydrogen atom attached to oxygen in the phenol molecule results in spectroscopic changes that should be functions of the mass change alone, since the force constants and the symmetry of the molecule remain unchanged. The variation in mass affects the ground state and excited state vibrational frequencies and the location of the O—O band, the latter through unequal changes of the zero-point vibrational energies in the ground and excited state.

O-deuteration decreases the frequency of the O—O band by 3 cm^{-1}. The vibrational frequencies are decreased on deuteration as expected, although the magnitudes seem anomalous. An additional anomaly appears in the apparent splitting of the O+783 band of phenol into O+772 and O+789 cm^{-1} in deuterophenol. This splitting occurs also in combinations and indicates that the phenol band at O+563 cm^{-1} (6b in Wilson's notation) was incorrectly assigned as a fundamental and instead should be assigned as O+783−222. O-substitution of $VH_3C_2H_5$, C_3H_7, C_4H_9, or C_6H_5 produces, in addition to the mass effect described above, a modification of the electronic structure of the molecule by inductive and resonance effects. This modification will change the value of the force constants as well as the height of the excited state. The shift in the position of the O—O band appears to be in accord with the known electrical properties of the substituents.

G11. Raman Spectrum of Hexamethylethane. RICHARD W. MITCHELL* AND FORREST F. CLEVELAND,** *Lynchburg College.*—Raman frequencies, relative intensities, and depolarization factors are reported for solutions of hexamethylethane (2,2,3,3, tetramethylbutane) in CCl_4 and in benzine. The exciting frequencies used are those of the 4047A and 4358A lines of mercury. Raman frequencies are measured by comparison with an iron arc spectrum. Relative intensities and depolarization factors are obtained by use of a Gaertner microdensitometer. The technique employed for determining depolarization factors is that developed by Cleveland.[1] The Raman data indicate that the equilibrium configuration for hexamethylethane is D_{3D}. The selection rules for D_{3D}, D_{3H}, and C_{3V} are worked out and discussed.

* Now at A & W College of Texas.
** Now at Illinois Institute of Technology.
[1] Forrest F. Cleveland, J. Chem. Phys. 13, 101 (1945).

G12. Molecular Orbitals for Methane and Ethane. F. A. MATSEN, *University of Texas.*—Molecular orbitals are formed from wave functions described only by the identification of the atoms with which they are associated, valence electrons alone being considered. The irreducible representations are CH_4, T_d: $\Gamma(\psi)=2A_1+2T_1$; C_2H_6, D_{3h}: $\Gamma(\psi)=3A_1'+3A_2''+2E'+2E''$; and C_2H_6, D_{3d}: $\Gamma(\psi)=3A_{1g}+3A_{2u}+2E_g+2E_u$, which factor the eighth- and fourteenth-order secular equations into blocks of two and blocks of two and three, respectively. Certain approximations and expansions yield the energies of the states as sums of interaction integrals between the "atomic" wave functions and the squares of these integrals. The electron configurations for the ground state become CH_4: $(A_1)_1^2(T_1)_1^6$; C_2H_6, D_{3h}: $(A_1')_1^2(A_2'')_1^2(E')_1^4(E'')_1^4(A_1')_2^2$; and C_2H_6, D_{3d}: $(A_{1g})_1^2(A_{2u})_1^2(E_g)_1^4(E_u)_1^4(A_{1g})_2^2$. The ordering of the terms in the ground state cannot be completely justified, but there is no ambiguity in the classication of ground-state and excited-state terms. The rotational barrier and second-order hyperconjugation in ethane will be briefly discussed in terms of these calculations.

Saturday Afternoon at 2:00

Anderson Hall, Room 109

(C. F. Squire presiding)

H1. X-Ray Determination of Thermal Expansion Coefficients of Crystals. M. Y. Colby and L. F. Connell, Jr., *University of Texas.*—The extremely high resolution which can be obtained from high angle Bragg scattering has been used to measure linear thermal expansion coefficients for a number of substances. Several workers in this field have reported discrepancies between the lattice expansion coefficients as measured by x-ray diffraction and the macroscopic coefficients obtained for large single crystals of the same material; e g., A. Gott[1] reported a 14 percent discrepancy for melt-grown potassium iodide in the range 20–200°C. Lattice expansion measurements on both melt- and solution-grown crystals of pure sodium chloride have been made in this laboratory in the range 20–300°C; a sensitive dilatometer for determination of the macroscopic expansion over the same range is under construction. The only values available at present for the macroscopic expansion of pure NaCl over a wide range are those of Eucken and Dannohl.[2] Their results for the range 20–300°C are 9 percent larger than the results of the lattice measurements made in this laboratory. This difference appears to support Gott's claim for a discrepancy between lattice and over-all expansion coefficients for alkali halides.

[1] A. Gott, Ann. d. Physik **41**, 520 (1942).
[2] A. Eucken and W. Dannohl, Zeits. f. Elektrochemie **40**, 814 (1934).

H2. Crystal Structure of Element 43, Technetium. R. C. L. Mooney, *Argonne National Laboratory.*—The element of nuclear charge 43 may be prepared by deuteron bombardment of molybdenum, and the chemical properties of a sample prepared in this way were studied by C. Perrier and E. Segrè in 1937. The element is also formed by fission. A sample containing the long-lived isotope was kindly prepared for us by Dr. G. W. Parker of the Clinton Laboratory in order to study the crystal structure of the compounds by x-ray analysis. Dr. Sherman Fried prepared several samples in microgram amounts, and one of these proved to be the element itself. The fact that the sample was metallic technetium was shown conclusively by the characteristics of the x-ray pattern itself. Like rhenium, osmium, ruthenium, and a number of other elements, technetium was found to crystallize in the hexagonal close-packed arrangement. The cell, which contains two atoms, has the following dimensions: $a=2.738\pm0.003$A and $c=4.393\pm0.006$A. Each atom has twelve neighbors, six at 2.706A and six at 2.738A. The density, assuming the atomic weight to be 99, is calculated to be 11.46.

H3. Small-Angle Diffraction in Lattices. Otto Halpern, *University of Southern California.*—The diffraction of light and material waves under angles which lie close to the direction of the incident beam has been investigated under various assumptions. It can be shown that the effects are independent of the exact angle of incidence but are strongly influenced by the specific nature of the imperfections of the lattice; in both respects the presently studied phenomena differ qualitatively from the diffraction into Laue spots of order larger than zero. The diffraction by a small ideal crystal (extinction neglected) under small angles has an integral cross section proportional to $N^{4/3}$ (N total number of atoms in the ideal microcrystal). An analogous result is obtained in the treatment of a "gas" composed of independent ideal microcrystals if the average distance between them is comparable with their linear dimensions. In the commonly encountered case of polycrystalline material, on the other hand, the result is radically changed because here the lattice errors are usually of the order of magnitude of the lattice constant; therefore the contributions of neighboring microcrystals to the scattering under small angles possess a large amount of coherence. Experiments, particularly those on electron diffraction by Kikuchi, will be discussed from the point of view here presented.

H4. Propagation of Waves of Finite Amplitude. Antonio Romero Juarez, *Universidad de Mexico.* (*Introduced by M. S. Vallarta.*)—The problem of the propagation of a sound wave is generally solved under the assumption that the amplitude of the wave is infinitely small. Under this assumption the theory of sound is developed. In the present paper some results are given concerning the study of the propagation of a plane wave whose amplitude cannot be considered infinitely small. The medium is assumed to be a gas, and a relation is derived between the velocity of a particle of the medium and the pressure. Both the isothermal and adiabatic cases are considered. A relation is also obtained giving the velocity of the wave at every point in terms of the pressure of the medium at that point.

H5. Ultrasonic Absorption in Water as a Function of Temperature.* Myron C. Smith and Robert T. Beyer, *Brown University.*—The absorption of ultrasonic radiation in water has been measured as a function of temperature in the range 0° to 80°C at three frequencies. The balance method of observing the radiation pressure was employed.[1,2] For temperatures above room temperature the measuring tank was placed in an insulated box containing a heating coil, while at values below room temperature a refrigerating unit was employed, with the expansion coil soldered to the outside of the tank. The results are accurate to 10 percent. Measurements are reported at 16.0, 22.5, and 27.3 megacycles. The values of $2\alpha/\nu^2\times10^{17}$ vary from 140 at 0°C to 13 at 80°C. Comparison is made with the theoretical values predicted by Hall[3] on the basis of a lag

in the rearrangement of the molecules during a compression, and a rather close agreement is shown.

* The research reported in this abstract was supported in part by the Office of Naval Research.
[1] E. Hsu, J. Acous. Soc. Am. **17**, 127 (1945).
[2] R. T. Beyer and M. C. Smith, J. Acous. Soc. Am. **18**, 424 (1946).
[3] L. Hall, Phys. Rev. **71**, 318 (1947); **72**, 537 (1947).

H6. The Form of the Seismic Disturbance Due to an Explosion. NORMAN RICKER, *Carter Oil Company.*—It has been shown in previous researches that a sudden explosion in a homogeneous and isotropic earth gives rise to a disturbance of a characteristic form, shaped by the earth's absorption, and which has been designated as a *seismic wavelet.* At relatively large distances from the explosion this form has been investigated, and the laws of propagation of the wavelet have been determined theoretically and checked experimentally in work previously published. At these large distances the spectrum of this wavelet lies in a low frequency range where there is no appreciable dispersion, and the wavelet assumes a symmetrical form. Near the explosion, however, the high frequency components of the shot pulse, which have not yet been filtered out by the earth's absorption, introduce an assymmetry to the wavelet form resulting from dispersion among these high frequency components. In the present paper, calculated wavelet forms are given for the displacement and velocity for unit numerical distance.

H7. The Balancing of Sedimentation by Electrophoresis in the Ultracentrifuge. M. L. RANDOLPH, *University of Virginia.** (*Introduced by J. W. Beams.*)—The method of balancing sedimentation in an ultracentrifuge by electrophoresis[1] has been extended and improved. The standard analytical centrifuge cell is adapted as a combination sedimentation and electrophoresis cell. The cell contains two side chambers, each filled with a saline solution in contact with a silver-coated electrode. These side chambers communicate directly with the test solution in the sector-shaped observation cell at its surfaces nearest the axis and periphery, respectively. The test solution is not at the isoelectric point. Thin Lucite partitions, containing many fine holes and covered with thin filter paper, separate the saline and test solutions. This avoids unnecessary mixing and prevents contamination of the test solution by the electrode products. The electrical current passes radially through the spinning sector-shaped observation cell in such a direction that the electrophoresis balances the sedimentation at one radial distance. This arrangement makes possible the separation and study of different molecular species whose mass or charge differ by very small amounts. Also, the homogeneity of various substances can be studied. The results obtained with human hemoglobin will be described.

* National Research Council Predoctoral Fellow at Virginia. Now at Tulane University.
[1] J. W. Beams, *Science in Progress, Second Series* (Yale University Press, New Haven, 1940), p. 258; Phys. Rev. **69**, 546 (1946).

H8. The A.C. Magneto-Resistance of Bismuth. ROBERT F. BLUNT, *Rice Institute.*—Measurements of the magneto-resistance of Bi in a constant magnetic field of 5000 oersteds were made using alternating currents with frequencies up to 3.5 megacycles. No decrease in magneto-resistance was observed as the frequency was increased, and in all cases it was nearly the same as that found with direct current. In the near infra-red it has been shown[1] that the magneto-resistance of Bi probably does not exist, and this experiment constitutes an attempt to find the frequency at which the magneto-resistance either disappears or begins to decrease. The experiment shows that up to 3.5 megacycles the magneto-resistance is normal. A possible reason for the disappearance in the infra-red is that magneto-resistance does not exist on the surface of a conductor. Thus a decrease should be observed when the skin effect becomes sufficiently pronounced. It is planned to make measurements at higher radio frequencies and also perhaps in the far infra-red to determine at what frequency and in what manner the observed magneto-resistance disappears.

[1] C. W. Heaps, Phys. Rev. **27**, 764 (1926). J. C. McLennan, Phil. Mag. **14**, 508 (1932).

H9. Temperature Coefficient of Resistance of Sodium-Ammonia Solutions. ANGUS PEARSON, *Rice Institute.**—The temperature coefficient of resistance of solutions of sodium in liquid ammonia has been measured for various concentrations. The resistance was determined by comparing with a cathode-ray oscilloscope the 500-cycle voltage across a conductivity cell with the voltage across a standard resistance. The concentration of the solution was determined by a titration method. In the region where two liquid phases coexist, the resistance variation as a function of the temperature depends in part on the change with temperature in the composition of the phase being investigated, according to

$$dR/dT=\partial R/\partial T+(\partial R/\partial C)(dC/dT),$$

where R, T, C represent, respectively, resistance, temperature, and concentration. When only one phase is present the second term is zero. It was found that dR/dT was always negative, and its magnitude increased as the temperature decreased.

* This research was financed through a fellowship granted by the Socony-Vacuum Oil Company, Inc.

Supplementary Programme

SP1. The 72-Day Isomer of Titanium (51).* C. E. Mandeville and Morris V. Scherb, *Bartol Research Foundation.*—Chemically pure TiO_2, irradiated by neutrons in the Clinton pile, was separated into phosphorus, iron, calcium, scandium, and titanium. A weak activity of long half-period was found in the titanium fraction. The half-period of this activity was given as 72 days by Walke *et al.*[1] The end point of the beta-ray spectrum was found to be 0.09 g/cm² as measured by absorption in aluminum, and the maximum gamma-ray energy was found to be 1.02 Mev by coincidence absorption. These values agree well with those reported by Walke *et al.* The beta-gamma coincidence rate was 0.9×10^{-3} coincidence per beta-particle, and was independent of the beta-ray energy, suggesting that the beta-ray spectrum of titanium (51) is simple. A gamma-gamma-coincidence rate of $(0.35\pm0.03)\times10^{-3}$ coincidence per gamma-ray was also observed. Some or all of the excited vanadium (51) residual nuclei then proceed to the ground state with the emission of two gamma-rays in cascade.[2]

* To be called after Session E if time permits.
[1] Walke, Williams, and Evans, *Proc. Roy. Soc.* **A171**, 360 (1939).
[2] Work supported by the Office of Naval Research.

SP2. The Scattering of Particles by an Attractive Center of Force Varying Inversely as the Cube of the Distance.* H. A. Wilson, *Rice Institute.*—This paper gives a solution of the problem in question which appears to be satisfactory. The usual expression for the asymptotic value of Bessel's function is shown to hold for complex values of the order. The scattering cross section is equal to

$$(\pi/k^2)\sum_{n=0}^{n=\infty}(2n+1)(e^{\pi\alpha_n}+1),$$

where $k=2\pi/\lambda$, λ = de Broglie wave-length of incident particles, $\alpha_n=(4\beta-(2n+1)^2)^{\frac{1}{2}}$, $\beta=8\pi^2my/h^2$, and $-y/r^2$ = potential energy of a particle at distance r from the attracting center.

* To be called after Session E if time permits.

SP3. A Spherical Shell Nuclear Model.* H. A. Wilson, *Rice Institute.*—Experimental results appear to show that many atomic nuclei have a set of nearly equally spaced energy levels with spacings of 0.387 Mev. The liquid drop model does not seem to offer any explanation of these levels. A model consisting of a hollow spherical shell is proposed, and it is shown that such a shell has a series of nearly equally spaced levels with spacings given by a function,[1] with no arbitrary constants, of the atomic number, the mass number, the radius, Planck's constant, and the mass of a nucleon. With spacings 0.387 Mev, this formula gives values of the radii of all nuclei agreeing nearly with those found by other methods. The energy of the shell model is discussed, and the shell is shown to be stable for uniform radial displacements. The root mean square amplitude of radial vibration of the shell caused by the ground-state vibrational energy is found to be about 7/10 of the mean distance between adjacent nucleons in the shell.

* To be called after Session E if time permits.
[1] H. A. Wilson, Phys. Rev. **69**, 538 (1946).

To Be Read By Title

T1. The Second Law of Thermodynamics from the Standpoint of the Equation of State. J. L. Finck, *J. L. Finck Laboratories.*—In this paper the concepts "equilibrium" and "reversibility" are examined from the standpoint of the number of independent variables which define a thermodynamic system. The endeavor is made to show that the number of independent variables which are selected is crucial to the basic concepts as well as to the second law of thermodynamics. If this number is less than the minimum required to define the system completely, the equation of state for the internal energy will be incomplete. It is our practice to employ incomplete equations of state, and this results in processes which we consider to be irreversible. The Kelvin-Planck and Clausius principles are shown to be somewhat related to the first law of thermodynamics, and their validity arises from the fact that the equations of state which are used are incomplete. If these equations were complete, i.e., if the number of independent variables were not less than the minimum required to describe the system completely, we would have complete conversion of heat into work, as well as work into heat. The difficulties in realizing complete equations are considered. The entropy concept is considered in detail and it is shown that there are serious limitations in its application.

T2. The 54-Minute Isomer of Indium (116).* Morris V. Scherb and C. E. Mandeville, *Barton Research Foundation.*—The fifty-four minute activity was induced in indium when a strip of indium metal of thickness 0.018 cm was irradiated by slow neutrons from a radium-beryllium source of strength 600 mc. The beta-gamma- and gamma-gamma-coincidence rates were reinvestigated.[1] In observing beta-gamma coincidences, corrections were made for cosmic-ray background, gamma-gamma coincidences, accidentals, and gamma-ray counts in the beta-ray counter. The decay of the source and its effect on the various corrections was taken into account. The beta-gamma-coincidence rate was found to be 1.3×10^{-3} coincidence per beta-ray and was independent of the beta-ray energy. This suggests that the beta-ray spectrum is simple. No genuine beta-gamma coincidences were observed for beta-ray energies greater than 0.7 Mev by Feather's more recent equation. The gamma-gamma-coincidence rate

was $(0.9\pm0.1)\times10^{-3}$ coincidence per gamma-ray recorded in the gamma-ray counter. The coincidence rates suggest that three gamma-rays are emitted per beta-particle in cascade.

* Supported by the Office of Naval Research.
[1] Langer, Mitchell, and McDaniel, Phys. Rev. **56**, 380 (1939).

T3. Properties of Radioactive Tantalum (182).* C. E. MANDEVILLE AND MORRIS V. SCHERB, *Bartol Research Foundation.*—The 100-day activity was induced in tantalum irradiated by slow neutrons in the Clinton pile. Separations were performed to remove phosphorous, calcium, potassium, tungsten, and hafnium as possible contaminants. The beta-rays had an absorption limit of 0.112 g/cm^2 in aluminum, corresponding to an energy of 0.36 Mev. The maximum gamma-ray energy was found to be 1.16 ± 0.1 Mev by coincidence absorption. No hard beta-rays were observed.[1] The beta-gamma-coincidence rate was 0.93×10^{-3} coincidence per beta-ray, independent of the beta-ray energy. This is consistent with the view that only one beta-ray spectrum is present. The gamma-gamma-coincidence rate was $(0.27\pm0.03)\times10^{-3}$ coincidence per gamma-ray. A comparison of these coincidence rates with those of Sc^{46}, using the same counters and geometry, suggests it to be unlikely that the two high energy gamma-rays of comparable intensity[2] are in cascade.

* Supported by the Office of Naval Research.
[1] Zumstein, Kurbatov, and Pool, Phys. Rev. **63**, 59 (1943).
[2] Rall and Wilkinson, Phys. Rev. **71**, 321 (1947).

T4. The Beta-Rays of Antimony (122).* C. E. MANDEVILLE AND MORRIS V. SCHERB, *Bartol Research Foundation.*—The 2.8-day activity was induced in metallic antimony, and irradiated by slow neutrons for about two hours in the Clinton pile. The short exposure time suppressed the 60-day period. Measurements were begun about 20 hours after removal from the pile. The genuine beta-gamma-coincidence rate was observed to decrease from an extrapolated value of 0.19×10^{-3} coincidence per beta-ray at zero absorber thickness to zero at 0.487 g/cm^2 of aluminum. The inner beta-ray group then has an end point at 1.19 Mev by Feather's equation. This group is coupled with gamma-radiation. The beta-ray distribution of higher energy, which leads to the ground state of the residual nucleus, has an absorption limit at 0.806 g/cm^2 in aluminum, 1.77 Mev by Feather's equation. The energy difference suggests a gamma-ray energy of 0.58 Mev. This value agrees with 0.57 Mev obtained by the thin magnetic lens.[1] The earlier estimate[2] of 0.80 Mev from semicircular focusing is obviously too high.

* Supported by the Office of Naval Research.
[1] Rall and Wilkinson, Phys. Rev. **71**, 321 (1947).
[2] Mandeville and Fulbright, Phys. Rev. **64**, 265 (1943).

T5. Minimization of Some Effects of Scattering in Experimental Determinations of XR for High Energy Particles. F. T. ROGERS, JR., *University of North Carolina.*—This note is in extension of an earlier one[1] upon the same general subject. Its object is to point out that in some instances, and within certain limitations, the configuration of the electrostatic field used in an experimental apparatus may lead to *XR*-determinations in which the subject scattering[1] produces only relatively small disturbing effects. Thus, for example, the cylindrical-electrode electrostatic analyzer has focusing properties[2] which may be used to minimize the effects of thin-window scattering: if the thin window be used as an "object" and if the particle detection be done in the corresponding "image" surface, then the lens-like focusing properties of the field may render the subject scattering unobservable and hence largely insignificant. In the instance of this particular field, however, the focusing properties are, to judge from the literature,[3] still incompletely understood for particles of higher relativistic speeds, although calculations now under way[4] may be expected to clarify them somewhat.

[1] F. T. Rogers, Jr., Phys. Rev. **71**, 833 (1947).
[2] A. J. Dempster, Phys. Rev. **51**, 67 (1937); R. Herzog, Ann. d. Physik **33**, 89 (1938).
[3] F. T. Rogers, Jr. and C. W. Horton, Rev. Sci. Inst. **14**, 216 (1943); Phys. Rev. **69**, 537 (1946).
[4] The author is indebted to Dr. Nathan Rosen for having pointed out valuable approaches to these calculations.

T6. Studies in the Progress of Ductile Fracture in a Notched Steel Bar.* MARGUERITE M. ROGERS AND PAUL E. SHEARIN, *University of North Carolina.*—In order to study the physical behavior of mild steel under conditions causing plastic flow (or brittle failure, if such failure occurs) a technique has been devised whereby the fracture area of a slow-bend test specimen is stained distinguishing colors at successive stages of crack propagation on a given specimen. In this way the crack contour can be ascertained progressively, and for the work involved in the propagation of the crack a given distance can be calculated. Bend specimens both with single notches and with four 15 percent Izod notches have been used. The latter specimen is designed to give a crack, the advancing head of which remains parallel to the rootline of the initiating notch.[1,2] The crack depth has, therefore, an accurately determinable value which can be correlated with many quantities, such as: (1) accumulated work, (2) stored elastic energy, (3) work associated with fracturing unit cross-sectional area, (4) temperature. In an effort to perceive something of the fundamental physical nature of brittle failure, it is desired to compare the relationship between these variables for those specimens which went brittle during the test and those specimens which remained ductile.

* Work supported by Office of Naval Research.
[1] C. Zener and J. H. Holloman, J. App. Phys. **17**, 69 (1946).
[2] P. E. Shearin, Phys. Rev. **71**, 832 (1947).

T7. On the Acceleration of Electrons by Cylindrical Cavities in TM_{01n} Modes. B. L. MILLER AND J. M. WOLF, *Bartol Research Foundation.**—For the acceleration of electrons moving at nearly light speed, the possibility of obtaining the effect of a number of cavities in series by using a single cavity in a TM_{01n} mode was considered. The length is limited by the fact that the electrons must emerge from the cavity before falling too far out of phase with the accelerating wave, the speed of which is greater than c. For a given available power at a definite frequency, the values of n and r are determined for which the electrons

gain maximum energy in passing through the axial electric field. The energy gained, ΔE, is

$$\Delta E = 2.9[r/(1+r)]^{\frac{1}{2}} \sin\{\tfrac{1}{2}n\pi[1+(4.81/n\pi r)^2]^{\frac{1}{2}}\}$$

in Mev per megawatt at 2800 megacycles. The maximum value of ΔE occurs for n equal to one (and $r=0.9$) so that there is no advantage in using a cavity of length greater than one-half guide wave-length in this mode. ΔE_{max} is 2 Mev.

* Work supported by the Office of Naval Research.

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